Refinement of Minimally Invasive Esophagectomy Techniques After 15 Years of Experience

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Abstract

Introduction In an effort to reduce the morbidity and mortality associated with open esophagectomy, a minimally invasive approach to esophagectomy was introduced at the University of Pittsburgh Medical Center (UPMC) in 1996. The objective of this article is to discuss the optimization and refinement of minimally invasive esophagectomy (MIE) techniques over the 15-year experience at UPMC. We also reviewed the literature on technical improvements in MIE.

Method Literature highlights for MIE and related meta-analyses comparing open esophagectomy and MIE were reviewed. The rationale and outcomes of techniques refinements were discussed in detail.

Results Most meta-analyses and systematic reviews confirm the feasibility and safety of MIE and suggest similar oncologic outcomes as compared with open esophagectomy. Since 1996, over 1,000 minimally invasive esophagectomies have been performed at UPMC. We have made several refinements to the MIE procedure that we believe significantly improved our surgical outcomes. It included adjustment of width of the gastric conduit, application of omental flap, and conversion from minimally invasive, three-hole esophagectomy to minimally invasive Ivor Lewis esophagectomy.

Conclusion MIE became a mainstay in the surgical treatment of esophageal cancer at UPMC. The technical improvements detailed above make the UPMC approach to MIE a feasible, safe, and efficient procedure.

Keywords Esophagectomy · Minimally invasive surgery · Esophageal neoplasm

Open esophagectomy is associated with significant mortality and morbidity, even when performed at an experienced center. Minimally invasive surgery is a rapidly evolving, advanced discipline that has experienced significant growth and increased demand in the past decade. Minimally invasive approaches have now been developed for a wide variety of intrathoracic and intra-abdominal procedures, and have become the standard of care in many instances. In an effort to reduce the morbidity and mortality associated with open esophagectomy, a minimally invasive approach to esophagectomy was introduced at the University of Pittsburgh Medical Center (UPMC) in 1996. Since that time, over 1,000
minimally invasive esophagectomies (MIEs) have been performed at UPMC. The objective of this article is to discuss the optimization and refinement of MIE techniques over the 15-year experience at UPMC. We also review the literature on technical improvements in MIE.

**Evolution of MIE at UPMC**

Prior to the development of MIE, the primary surgeons had acquired extensive experience with open esophagectomy approaches (transhiatal, transhiatal, and thoracoabdominal). With the introduction of video-assisted thoracoscopic surgery (VATS) and laparoscopic techniques in the early 1990s, the authors had also gained significant experience with the use of these minimal approaches within the chest and abdomen in a wide variety of applications (e.g., thorascopic lung resection and laparoscopic Nissen fundoplication). When contemplating a novel, minimally invasive, surgical approach, the surgeon must remain acutely aware that the fundamental surgical principles of a given procedure must be accomplished without “cutting corners,” and the final result should ideally be equivalent to (or better than) that obtained with the corresponding open surgery.

The first efforts at MIE in 1996 utilized a transhiatal approach. The transhiatal approach simplifies patient positioning and does not require single-lung ventilation. The primary disadvantage of the transhiatal approach is a small working space through the hiatus, which allows only limited access to the middle and upper third of the esophagus and makes thoracic lymph node dissection extremely difficult. Because of these limitations, modified McKeown (three-hole) approach was developed that became the dominant MIE procedure over the next 5 years. This approach included right VATS to mobilize the thoracic esophagus, laparoscopy to prepare the gastric tube, and a left cervical esophagogastric anastomosis. Using the three-hole approach, MIE could be performed safely (1.4 % mortality) with stage-specific survival that was equivalent to previously published open series.

With experience, it became apparent that the proximal extent of dissection could be adequately accomplished and the anastomosis performed through the chest in the vast majority of cases, obviating the need for a neck incision and its associated morbidity. Therefore, a completely laparoscopic thoracoscopic Ivor Lewis esophagectomy with complete two-field lymph node dissection has become our preferred approach for MIE. Compared with transhiatal approach, the advantages of this approach include better exposure and access to the chest, increased potential for complete resection, better gastric margins, improved lymph node dissection in the mediastinum, and lower rates of anastomotic complications, recurrent laryngeal nerve injury, and pharyngoesophageal swallowing dysfunction.

As MIE techniques have been developed and refined, many advantages of MIE have become apparent, including reduced morbidity, mortality, and shorter hospital stays. Even though elevated body mass is usually a predictor of complications after major surgery, obesity has not been found to be a risk factor for mortality, postoperative complications, or prolonged hospitalization after MIE. Because of the potential for major postoperative complications after open esophagectomy, there is increasing interest in competing endoscopic therapies for T1 esophageal cancer. Pennathur and colleagues demonstrated that MIE can be performed safely in patients with T1 esophageal cancer with good long-term results, supporting the continued use of esophagectomy as the standard treatment for patients with T1 esophageal cancer.

**Literature Highlights for MIE**

During the last 15 years, over 200 research papers have been published on MIE. In 2009 and 2010, several meta-analyses were published comparing open esophagectomy and MIE. In one meta-analysis, Biere and colleagues compared total MIE with hybrid MIE (thoracoscopy and laparotomy) approaches and open transthoracic esophagectomy (TTE). Ten studies were identified, comprising 1,061 patients. The meta-analysis showed no significant differences between total MIE and TTE with regard to major morbidity (odds ratio (OR)=0.88; 95 % confidence interval (CI), 0.35–2.14; p = 0.78) or pulmonary complications (OR=1.05; 95 % CI, 0.42–2.66; p = 0.91). A trend toward a reduced mortality was seen in the MIE group, although statistical significance was not reached. Additionally, significantly fewer cases of anastomotic leakage were reported in the hybrid MIE group (thoracoscopy and laparotomy) than in the open TTE group (OR = 0.51; 95 % CI, 0.28–0.95; p = 0.03).

Nagpal and colleagues performed a meta-analysis to compare the outcomes of open esophagectomy with the outcomes of MIE and hybrid MIE. Twelve studies were included in the analysis that included 672 patients who underwent MIE or hybrid MIE and 612 patients who underwent open esophagectomy. There were no significant differences in 30-day mortality; however, the patients who underwent MIE had less blood loss, shorter hospital stay, and reduced total morbidity and respiratory complications. Sgourakis and colleagues screened 71 studies and identified 8 studies with 1,008 participants (512 MIE/496 open). They found patients who had undergone open esophagectomy had lower incidence of strictures, while patients who had undergone MIE had lower overall morbidity. MIE and open procedures allowed comparable lymph node removal and exhibited similar 30-day mortality and 3-year survival. A systematic review from Verhage and colleagues also attempted to answer whether minimally invasive surgery
for the management of esophageal cancer improved short-term outcomes as compared with conventional open surgery. These authors reviewed ten case-controlled studies and one earlier systematic review (amassing 496 patients who had undergone open esophagectomy and 616 patients who had undergone some type of MIE) and found that MIE resulted in lower overall complication rates, shorter ICU and hospital stays, and less blood loss during surgery. In contrast, Decker and colleagues conducted a meta-analysis that focused on surgical and oncologic outcomes and included 46 original series (1,932 patients). The overall conversion rate of MIE to open surgery was 5.9%. Mortality after MIE was 2.9%, and morbidity was 46%. Pulmonary complications occurred in 22% of patients who underwent MIE, leakage in 8.8%, and vocal cord palsy in 7.1%. Decker concluded that the morbidity and mortality of MIE were not less than that of radical open esophagectomy performed at an experienced center and suggested that MIE should be considered as an investigational, still-evolving treatment for invasive esophageal cancer.

A systematic review published in 2012 compared the oncologic outcomes of MIE and open esophagectomy through an analysis of 17 case-controlled studies comprising 1,586 patients (718 open, 494 MIE, and 386 hybrid MIE). Pathologic stage was similar between the surgical approaches. Significantly more lymph nodes were harvested from patients who had undergone MIE, likely because of improved visualization of the lymph nodes during thoracoscopy. Mortality at 30 days and 5 years after resection did not differ between MIE and open esophagectomy.

In summary, most meta-analyses and systematic reviews confirm the feasibility and safety of MIE and suggest similar oncologic outcomes as compared with open esophagectomy. Moreover, the studies collectively point towards the potential for improved short-term outcomes after MIE. With the improvement and refinement of MIE techniques, MIE has been accepted and adopted by more and more thoracic surgeons. In a study examining MIE utilization in England, 18,673 esophagectomies were performed over the 12-year study period. The use of minimal access surgery increased exponentially over time (from 0.6% in 1996/1997 to 16.0% in 2007/2008). Interestingly, a trend was observed suggesting that 1-year survival was better in patients who underwent MIE than in patients who underwent open esophagectomy (OR = 0.68; 95% CI = 0.46–1.01; p = 0.058).

Recently, the first results of a phase II study (Eastern Cooperative Oncology Group, ECOG 2202, NCT00063986) evaluating the results of MIE in a multi-institutional setting were reported. This multicenter cooperative group trial enrolled 106 patients. The preliminary results indicate low morbidity and a mortality rate < 2%. Median intensive care unit stay was 2 days. At a mean follow-up of 19 months, the estimated 3-year overall survival for the entire cohort was 50%. Stage-specific survival was similar to open series.

Refinement of Minimal Invasive Esophagectomy Techniques in UPMC

Several refinements to the MIE procedure have been made, with increasing experience, over the last 15 years. The evolution of techniques highlighted below has significantly improved the observed surgical outcomes. The technique of MIE has recently been detailed in its entirety elsewhere.

Width of the Gastric Conduit

There is wide variation in the methodology employed in the preparation of the gastric conduit reported among the largest open series. Some authors advocate the use of the whole stomach to preserve the native collateral blood supply to the gastric tip in an effort to minimize the risk of ischemia and anastomotic complications. Other groups support the use of a tubularized conduit to optimize conduit length and function after advancement into the chest or neck. At UPMC, the thoracic surgeons have advocated the use of a tubularized conduit to optimize the functional outcomes. Early in the UPMC experience, a very narrow gastric tube (3 to 4 cm in diameter) was employed and was noted to be associated with an increase in gastric tip necrosis and anastomotic leaks. By increasing the diameter of the gastric conduit to 5–6 cm, a decrease in anastomotic complications has been observed (Fig. 1).

Omental Flap

The omental flap is a useful technique to prevent anastomotic leaks, due to its ability to induce neovascularization in avascular areas and its ability to function in the presence of an
established infection. It was described by Goldsmith in 1968, and has been utilized in a wide variety of plastic and orthopedic operations. The omental flap may decrease the incidence of anastomotic leak by inducing neovascularization and increasing collateral blood flow. Vascular endothelial growth factor likely plays a major role in this process. An omental flap can also seal microscopic leaks until complete healing occurs. Having the omentum wrapped around an esophageal suture line is expected to increase blood flow into the area, reduce the possibility of ischemia, and potentially decrease the opportunity for stricture development.

After personal communication in 2008 with Dr. Earl Wilkins, Professor Emeritus at the Massachusetts General Hospital, the use of omental flaps was explored in MIE. A 3-cm wide, 8–10 cm long omental pedicle, originating from the upper greater curvature of the stomach, is created laparoscopically (Fig. 2). The key steps of the laparoscopic technique are (1) dissecting the coloepiploic attachments, (2) dividing of the anastomotic arterial branches, (3) preventing enterotomy and damage to the blood supply of the omental flap, (4) fixing the pedicle to the gastric conduit temporarily, (5) transposing the pedicle into the mediastinum, taking care to avoid twisting the gastric greater curvature and the flap itself, (6) wrapping the pedicle around the anastomosis, and (7) applying an Endostitch suture to the top of the anastomosis (Fig. 2).

Preliminary observations suggest that if there is an anastomotic leak, it will usually be contained and well controlled by Jackson-Pratt (JP) drainage. The primary disadvantage of laparoscopic harvest of an omental flap is that it can be time-consuming (30–60 min), especially in patients with multiple prior surgeries. Currently, the omental flap technique is utilized selectively, most commonly in high-risk patients who have undergone neoadjuvant radiation or chemoradiation therapy.

Published studies on the construction of an omental flap around the esophagogastric anastomosis are still limited. Karaoglanolu and colleagues reported 132 patients with pedicled omentum wrapped around the esophagogastric anastomosis. Only two patients (1.5 %) were identified as having a clinically significant anastomotic leak in the postoperative period. Bhatalso reported that use of pedicled omentum in esophagogastric anastomosis can decrease the leak rate. Anastomotic leak developed in 14 of 97 patients (14.4 %) without an omental flap, but occurred in only 3 of 97 patients (3.1 %) with an omental flap. Zhang and colleagues showed that the omental graft was also a very useful adjunct to handsewn anastomosis after esophagogastrectomy for carcinoma of the esophagus. Dai and colleagues conducted a prospective randomized clinical trial to study the effect of omental flap on anastomosis of esophagectomy. They found that wrapping the pedicled omental flap around the esophagogastric stapled anastomosis site significantly decreased the incidence of anastomotic leakage and strictures.

Conversion from Minimally Invasive, Three-Hole Esophagectomy to Minimally Invasive Ivor Lewis Esophagectomy

Regardless of the type of incision used, creation of an anastomosis in the neck is associated with unique complications. Anastomotic leak, stricture, and injury to the recurrent laryngeal nerve are relatively frequent when dissection is performed in the neck. In addition, a small group of patients will develop significant problems with esophageal transit and aspiration, despite intact recurrent laryngeal nerves. Although these complications are rarely reported as fatal, they may have a profound impact on the risk of aspiration pneumonia, clearance of pulmonary secretions, and patients’ overall quality of life. Avoidance of these complications is a major benefit of intrathoracic anastomotic techniques during esophagectomy. Compared with a cervical anastomosis, other major advantages of an intrathoracic anastomosis are reduction of
the tension on the anastomosis and reduction of ischemia at
the tip of the gastric conduit, resulting in a lower incidence
of anastomotic leaks. To this point, many surgeons have
attempted minimally invasive intrathoracic anastomosis.
Watson reported two cases of esophagectomy performed
by hand-assisted laparoscopy with a thoracoscopic intratho-
racic anastomosis in 1999.29 Nguyen reported one case of
minimally invasive Ivor Lewis esophagectomy in 2001.30
We began to perform minimally invasive, Ivor Lewis esoph-
gectomy in 2002, and reported our initial experience of 50
patients in 2006.1 In that report, we showed that a minimally
invasive Ivor Lewis esophagectomy was feasible and that
the technique was reproducible. The rate of perioperative
complications, including anastomotic leak, pneumonia, and
recurrent nerve injury, was quite low. Nguyen has since
reported a series of 104 consecutive MIEs that included 51
Ivor Lewis MIEs. The rate of perioperative complications
was low (11.8 %) in patients who had undergone Ivor Lewis
MIE. Additionally, Ivor Lewis MIE was associated with a
shorter operative time and less blood loss compared with
MIE with a cervical anastomosis.31

It is becoming clear that adequate lymph node dis-
section is required for accurate staging of esophageal
cancer.32 One of the potential advantages of the Ivor
Lewis approach is better exposure and improved lymph
node dissection in the mediastinum compared with tran-
shial esophagectomy techniques. Detailed lymph node

Fig. 3 Advancement of the specimen and gastric conduit into
the chest. (Reprinted from,17
with permission from Elsevier)

Fig. 4 Schematic of anvil in esophageal stump and stapler body in
the gastric conduit during EEA anastomosis
dissection is recognized as an important component in optimizing prognostication and clinical outcomes following esophagectomy.

For all of these reasons, minimally invasive Ivor Lewis esophagectomy is viewed as the primary choice for esophageal cancer at the gastroesophageal junction. An updated retrospective series of 530 patients who underwent Ivor Lewis MIE and 481 patients who underwent MIE with a neck anastomosis at UPMC was presented in April 2011 at the American Surgical Association Annual Meeting. In this large study of 1,011 patients who had undergone MIE, overall operative mortality was 1.68%, median ICU stay was 2 days, and median hospital stay was 8 days. Postoperative vocal cord dysfunction and acute respiratory distress syndrome were significantly reduced by the use of Ivor Lewis MIE when compared with three-hole esophagectomy with a neck anastomosis.33

After completing laparoscopic gastric mobilization with preparation of the gastric conduit, as well as complete esophageal mobilization within the chest, the esophageal specimen and attached gastric conduit are advanced into the chest using a gentle, steady, hand-over-hand technique with Snowden forceps (Fig. 3). It is critical that the gastric tube remains properly oriented with the staple line facing the lateral chest wall and the greater curve side of the gastric conduit facing toward the spleen to ensure proper anatomic orientation. This alignment is mandatory to avoid spiraling or twisting of the conduit. The suture fixing the specimen to the conduit is cut, and the specimen is removed through a posterior thoracic access incision. To prevent migration of the conduit back into the abdomen, tacking sutures can be used to secure the conduit to the diaphragm, if necessary.

The intrathoracic anastomosis is performed utilizing an end-side technique, employing the end-to-end anastomosis (EEA) stapling device. The 28-mm anvil of the EEA stapler is routinely utilized. The EEA anvil is secured with two purse-string sutures of 2-0 Surgidac Endostitch.34 Once the anvil is secured, the gastric conduit is advanced to the apex of the chest, and the tip of the gastric conduit is opened with ultrasonic shears along the right side of the lesser curve staple line. The surgeon and the first assistant grasp the edges of the conduit with Snowden forceps to maintain proper alignment and prevent twisting of the conduit. The lubricated EEA stapler handle is then inserted into gastric conduit using a foot-in-sock motion. The anvil is docked to the EEA stapler, and the esophagogastrectomy anastomosis is completed (Fig. 4). A JP drain is then positioned posterior to the anastomosis, and a 28-Fr chest tube is directed posteriorly to the apex of the chest. With careful technique, anastomotic complications from minimally invasive Ivor Lewis esophagectomy requiring surgical intervention are lower (4%), compared with open procedures (e.g., transhiatal esophagectomy, 5–12%).33

**Future Developments**

Our future research interests include determining whether the omental flap improves anastomotic integrity and whether robot-assisted surgery improves outcomes after MIE. A systematic review of the use of the da Vinci surgical robot in esophageal and gastric resection identified 130 patients in nine studies who underwent robot-assisted MIE for esophageal malignancy. Comparing these studies of outcomes after robot-assisted MIE to the recent analysis of Verhage and colleagues demonstrated improved operative outcomes and shorter hospital stays after robot-assisted MIE as compared with open esophagectomy. In terms of short-term oncological outcomes, robot-assisted esophagectomy was at least equivalent to the open esophagectomy for esophageal cancer.35

Recently, a multicenter, randomized trial comparing traditional invasive vs. minimally invasive esophagectomy was initiated in the Netherlands. Sixty patients will be enrolled per arm. This study will provide more information about the postoperative complication of MIE and its oncological success compared with traditional open esophagectomy.36 MIE was initiated at UPMC in 1996 and over 15 years became a mainstay in the surgical treatment of esophageal cancer. The technical improvements detailed above make the UPMC approach to MIE a feasible, safe, and efficient procedure.

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